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Markov Random Fields on 3D Polygonal Meshes

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Abstract

Markov Random Fields (MRF) have been used extensively for solving Image Analysis problems at all levels. The local property of MRF makes it convenient for modeling dependencies of image pixels, and the MRF-Gibbs equivalence theorem provides a joint probability in a simple form, making MRF theory useful for statistical Image Analysis. The majority of these MRF applications are built on a regular pixel grid, even though MRF theory, in its general form, does not require regularity of the sites.

Despite the simplicity and the flexibility of the formulation, MRF has not yet found its application in the field of 3D mesh modeling. Still, many concepts used in Image Analysis have over time been generalized and applied to mesh surfaces. This presentation investigates the use of MRF for formulating priors on 3D surfaces represented as triangle meshes.

Defining MRF on surface meshes is straightforward if one uses mesh connectivity to define the MRF neighborhood. The MRF site can be assigned to any of the basic entities of a triangular mesh — vertices, edges or faces. All three possibilities are discussed here. The idea is addressed by focusing on mesh smoothing, which is of great interest in many applications of geometry processing, e.g., computer vision and reverse engineering.

Firstly, a mesh-smoothing vertex process is described. It is a process that combines a smoothness prior described through MRF with the simple observation model into MAP-MRF framework. Smoothing

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is done by iterative vertex replacement, using Metropolis sampling and simulated annealing scheme.

An edge process for detecting features (ridges) is shown next, where the feature-detecting function allows specifying the sharpness of the ridge. Edge process can be coupled with the vertex process in a feature-preserving mesh-smoothing method.

Lastly, a face process for normal filtering is presented. Filtering face normals is a first step in a different mesh smoothing procedure, and can also be coupled with the edge process.

The biggest challenge in formulating MRF on triangle meshes is dealing with its irregularity. A vertex can have a different number of adjacent vertices, and an edge can have a different number of adjacent edges. As a result, for example, one can not directly compare the potentials corresponding to two vertices.

Preliminary but promising experimental results are presented, proving the feasibility and demonstrating the use of MRF on triangular meshes. Developed priors and the optimization methods are discussed, and some possible improvements suggested.